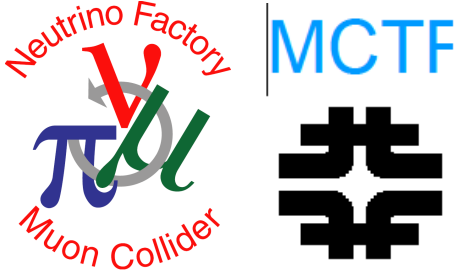


# Lattices for Guggenheim Cooling

R. B. Palmer (BNL)

FNAL Mini-Workshop

10/22/09



1. Required magnetic fields for cooling in solenoid (or HCC)
2. Effects of single and double periodicity
3. RFOFO lattices for 201 & 402 MHz
4. Efficiency
5. Magnetic Insulation
6. 805 MHz lattice
7. Conclusion

# Solenoid fields for Cooling

For cooling in hydrogen, without windows, at  $\approx \gamma=2$  (chosen to avoid rapid increase in  $dp/p$ ):

$$\text{Equilibrium emittance } \epsilon_{\perp}(\text{equilib}) = \frac{C\beta_{\perp}}{\beta_v} = \frac{2 \gamma C m_{\mu}}{c B}$$

$$B \approx \frac{10 \cdot 10^{-3}}{\epsilon_{\perp}(\text{equ})}$$

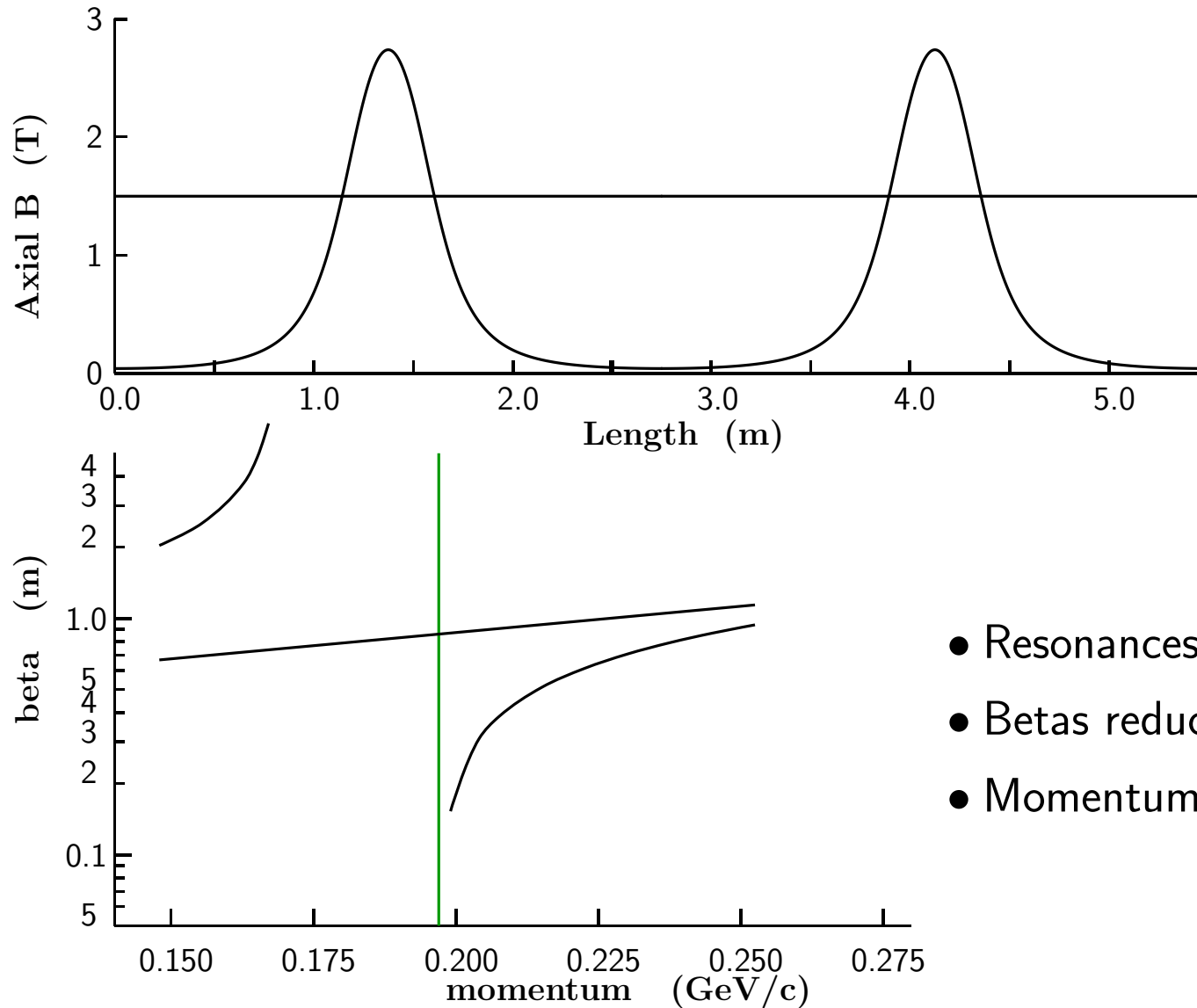
With emittance exchange giving  $J_x = J_y = J_z$  then

$$B \approx \left(\frac{3}{2}\right) \frac{10 \cdot 10^{-3}}{\epsilon_{\perp}(\text{equ})}$$

Stage	rf freq MHz	emit $\pi$ mm	B T
1	201	2	3.75
2	401	1	7.5
3	805	0.32	23

- In HCC these are indeed the approximate axial fields needed
- But in a periodic lattice, the  $\beta_{\perp}$  at the absorber can be less than the above

## Decreasing beta in Solenoids by adding periodicity

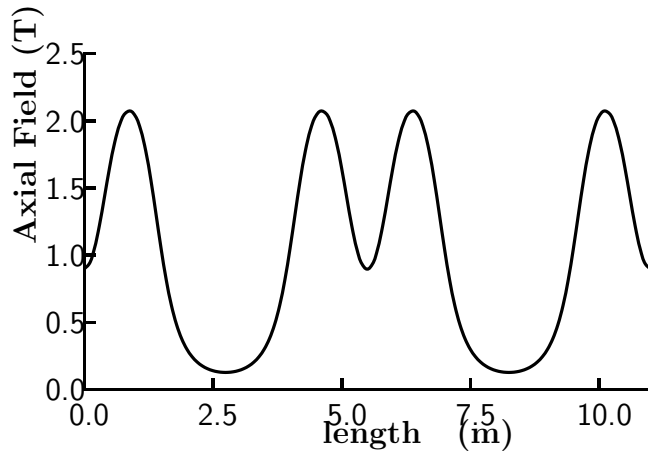
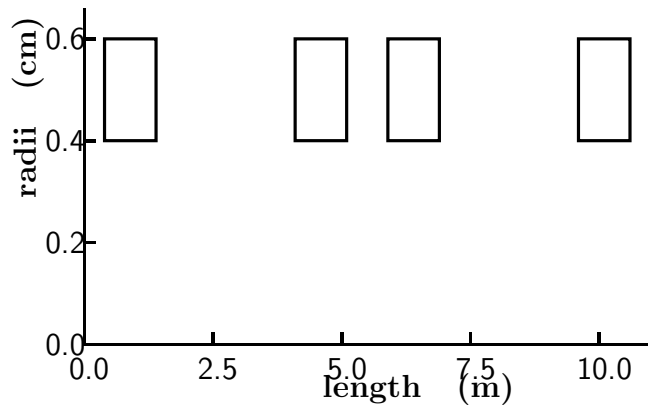


- Resonances introduced
- Betas reduced locally
- Momentum acceptance small

In practice, the solenoid fields are usually altering to avoid a buildup of angular momentum - our homework will show how this occurs

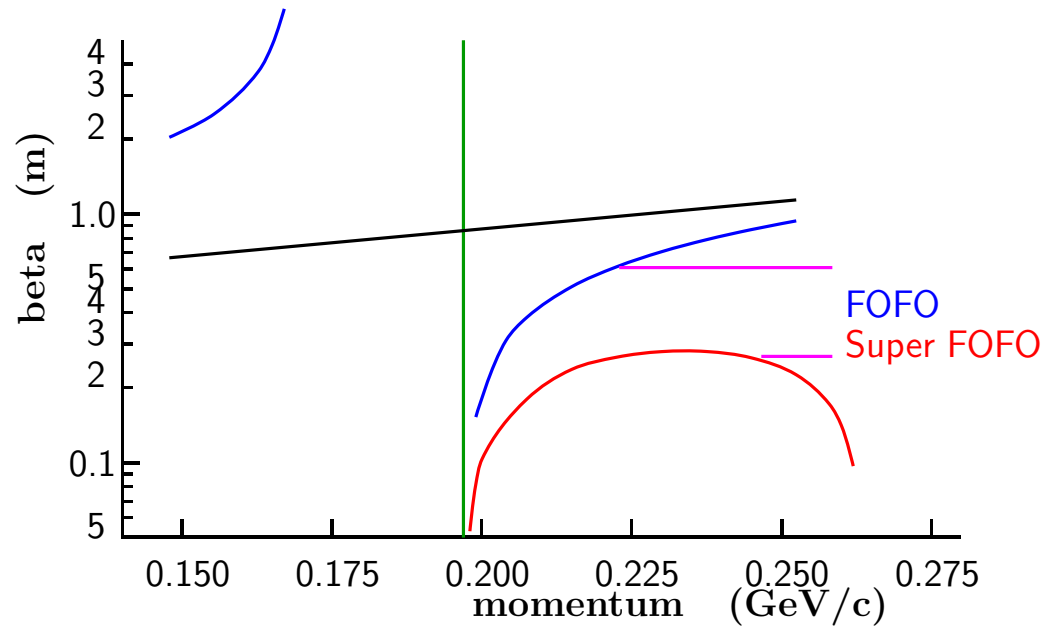
# Super FOFO

Double periodicity



## Polarities:

shown:		+	+		+	+	
SFOFO:		+	+		-	-	
RFOFO:		+	-		+	-	



- Beta lower over finite momentum range
- Beta lower by about 1/2 solenoid

## RFOFO chosen for Ring/Guggenheim

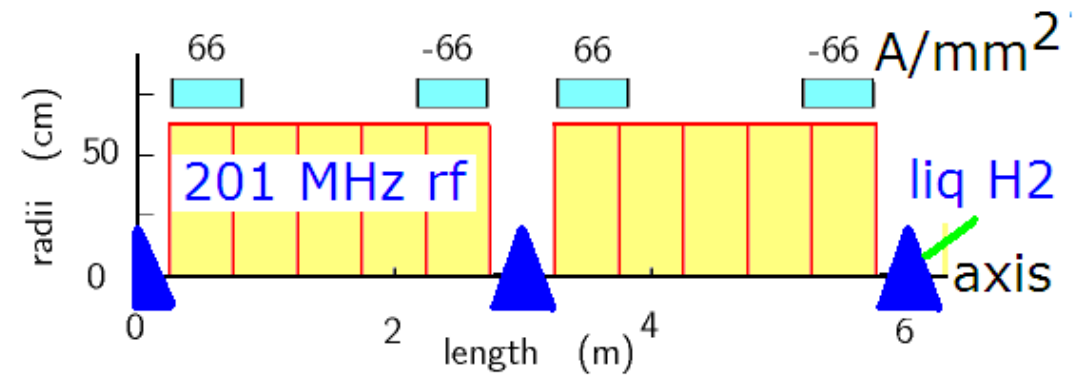
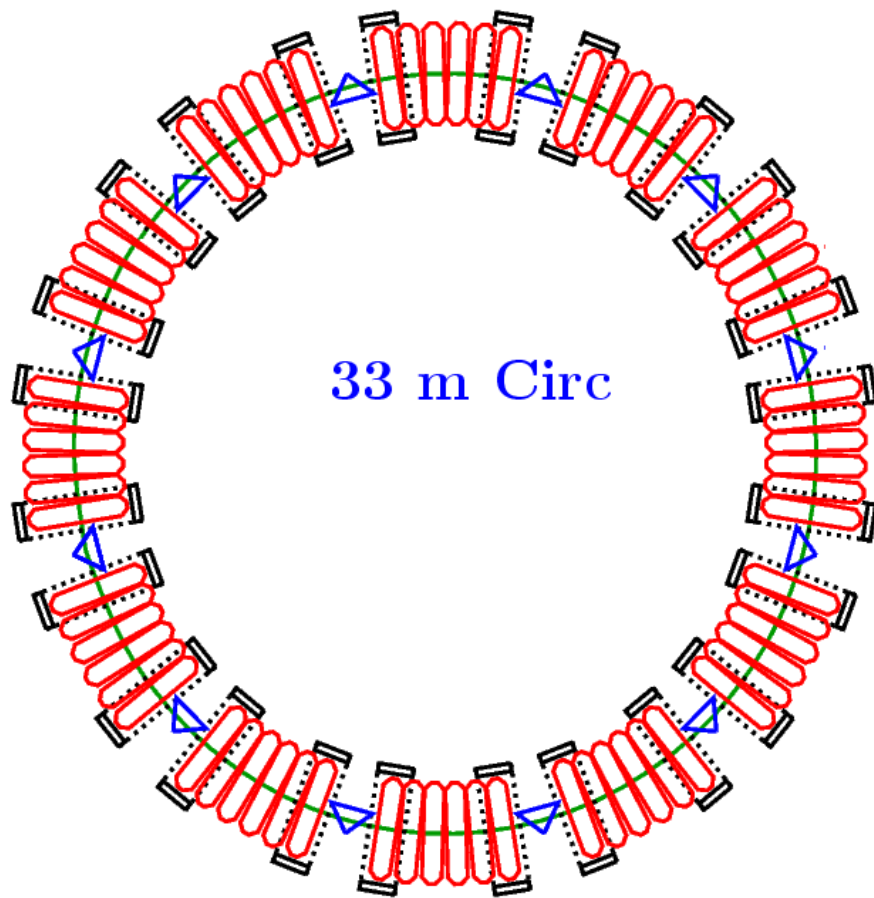
because all cells identical  
removes 1/2 the resonances

# RFOFO Ring

Simulated with realistic Maxwellian Fields

But not fields from actual solenoids

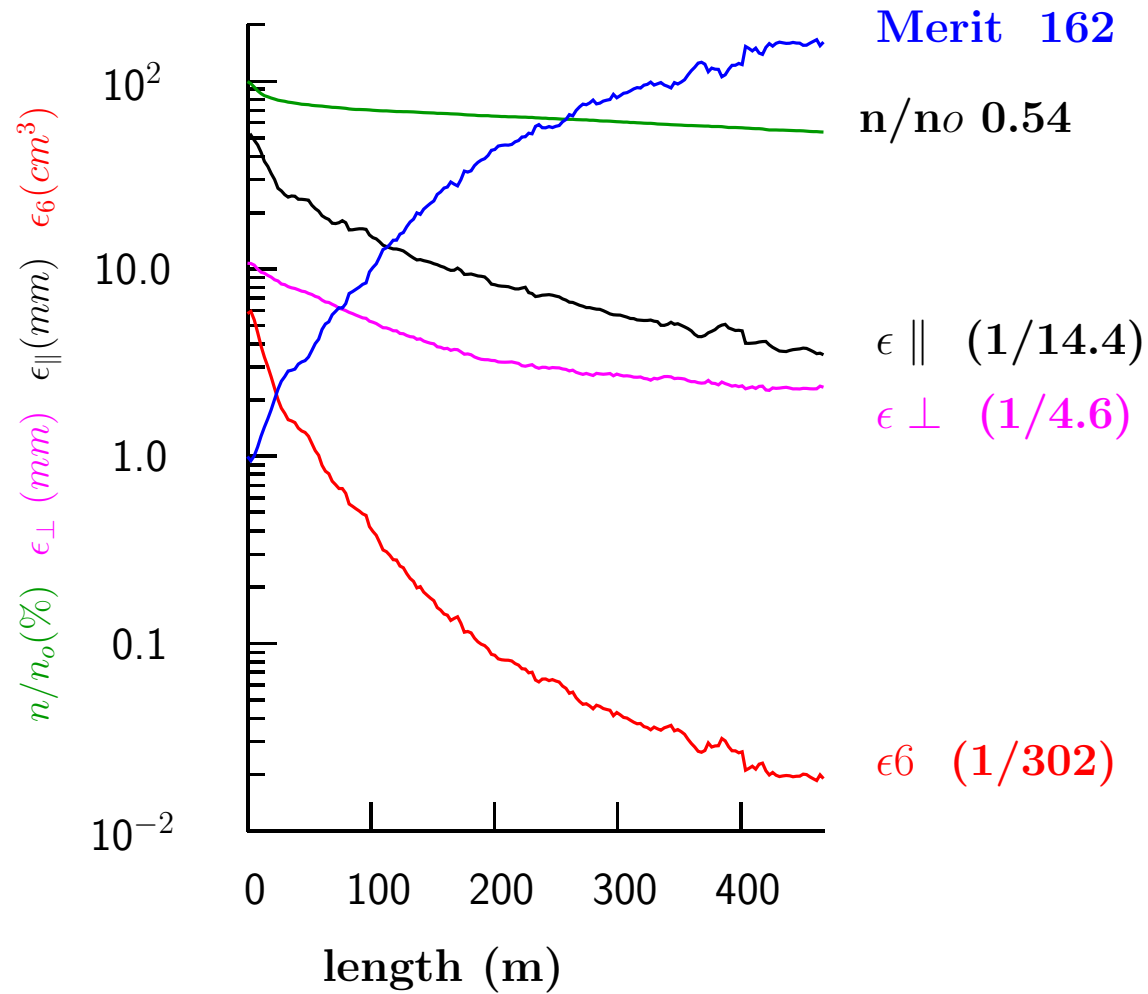
Simulations with real fields give the same results



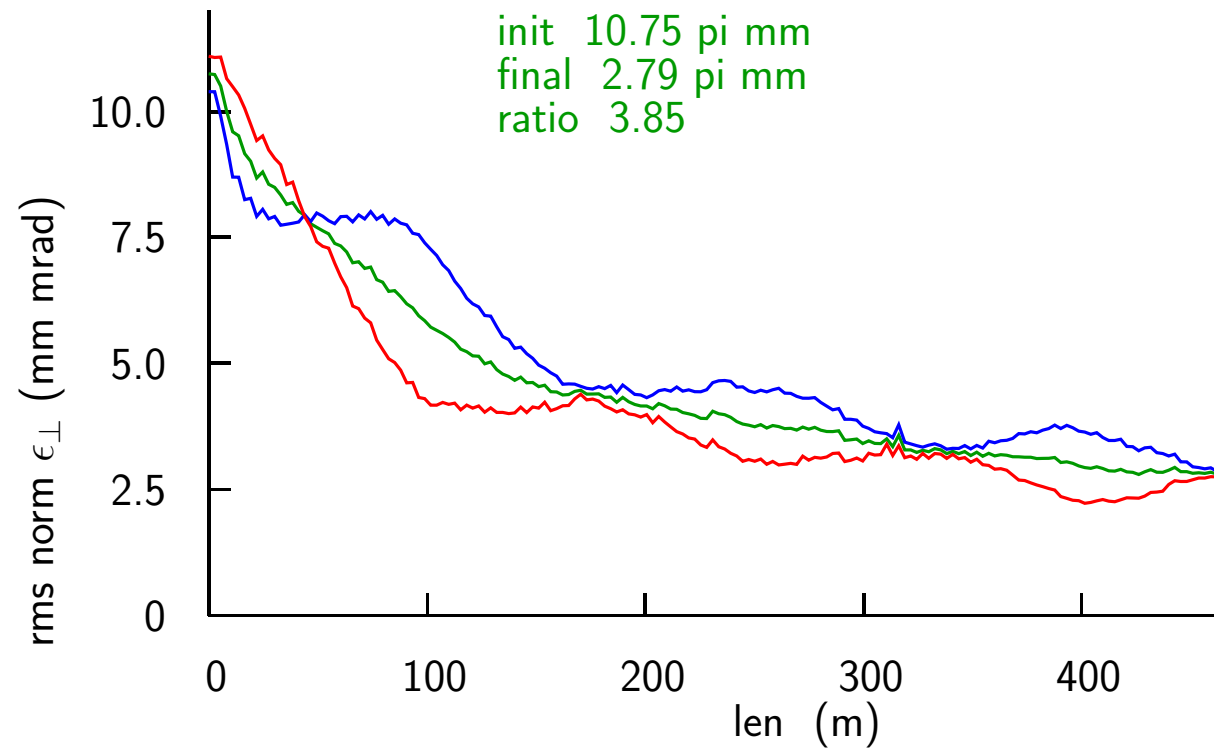
Lattices of this type ok at 201 and 402 MHz

# ICOOL Simulated Performance

- Assume a Guggenheim will behave like the ring
- No Windows



## An interesting detail



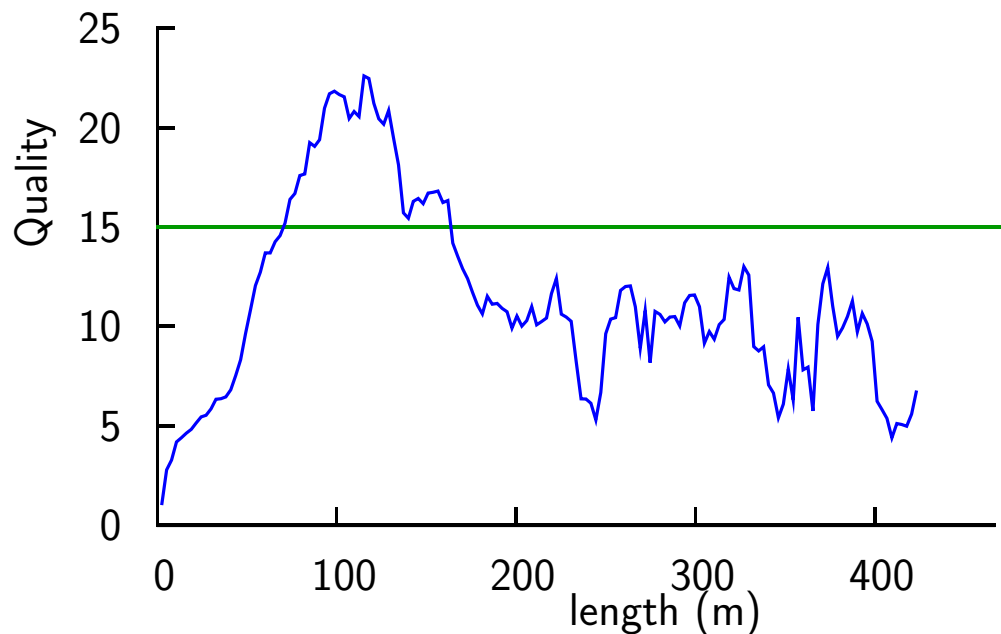
The emittance exchange is initially all in x

But there is enough phase rotation in x,y to eventually give nearly symmetric cooling

# Efficiency vs. length for old RFOFO

$$\text{Define : Efficiency} = Q = \frac{d\epsilon_3/\epsilon_3}{dn/n}$$

- Mismatch and Scraping losses at start
- Decay losses as emittances approach equilibrium at end
- Sweet region in between ( $Q \approx 15$ )
- If tapered then the entire channel is operated in the sweet region

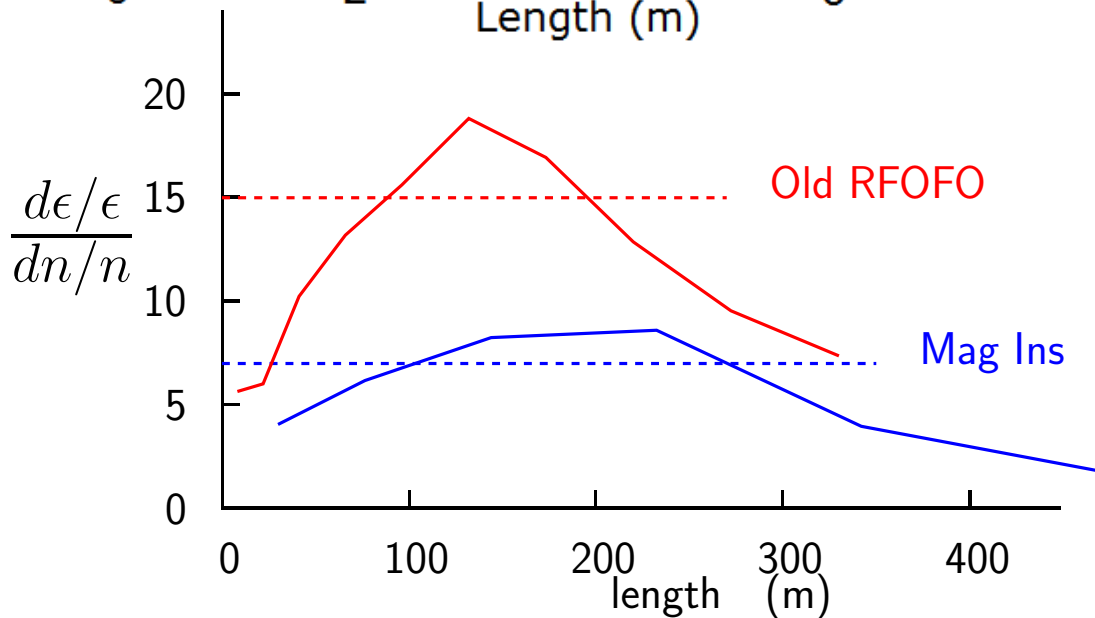
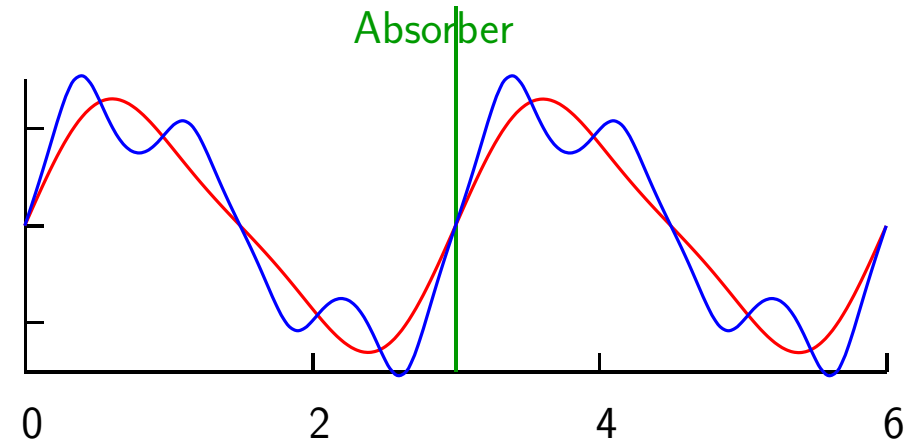
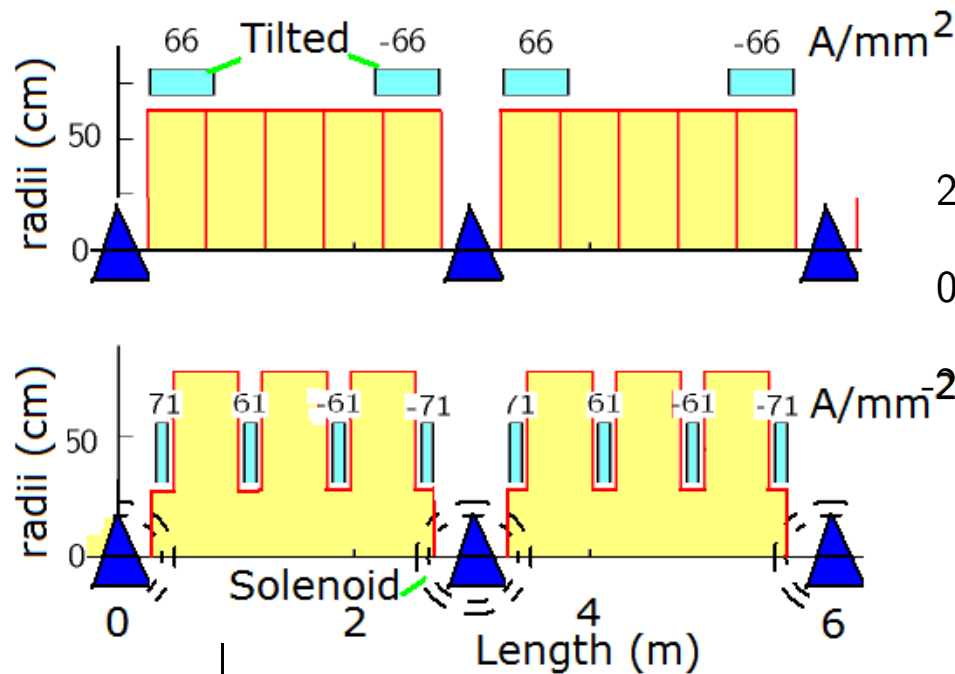


Required 6D cooling in RFOFO lattices from 280,000 to 2.1 (mm<sup>3</sup>) So expected transmission if tapered

$$\frac{n_{final}}{n_{initial}} = \left( \frac{2.1}{115,000} \right)^{1/15} = 0.48$$

Good

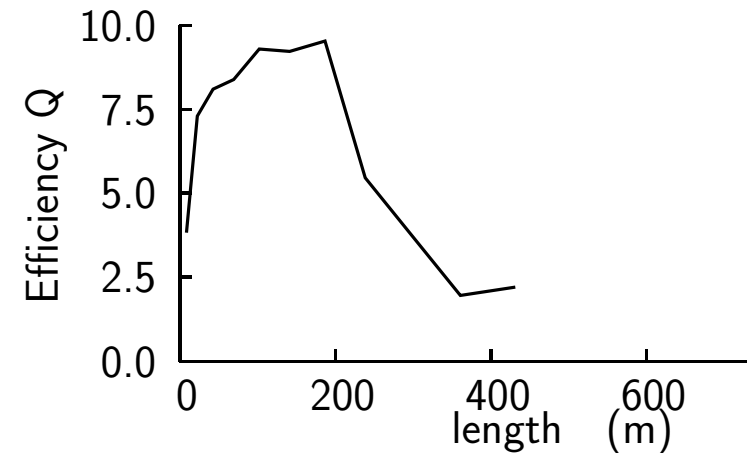
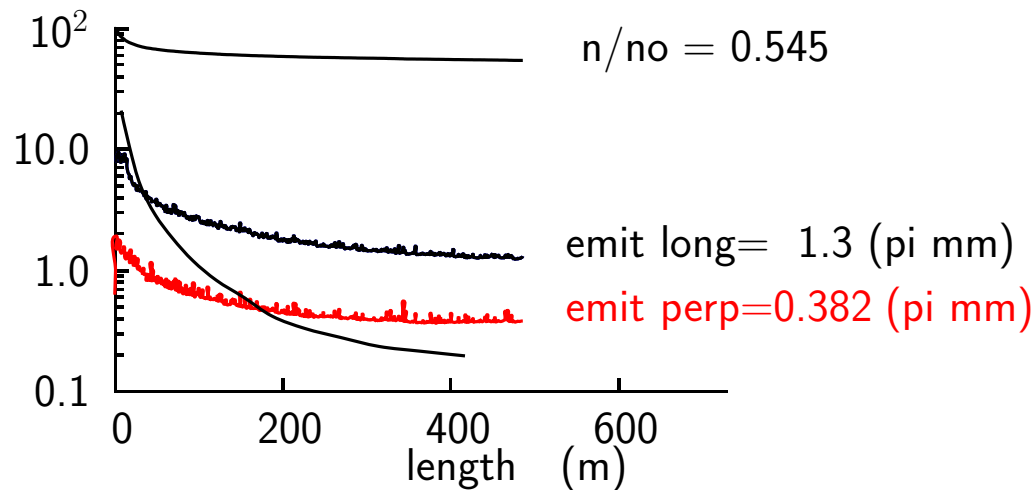
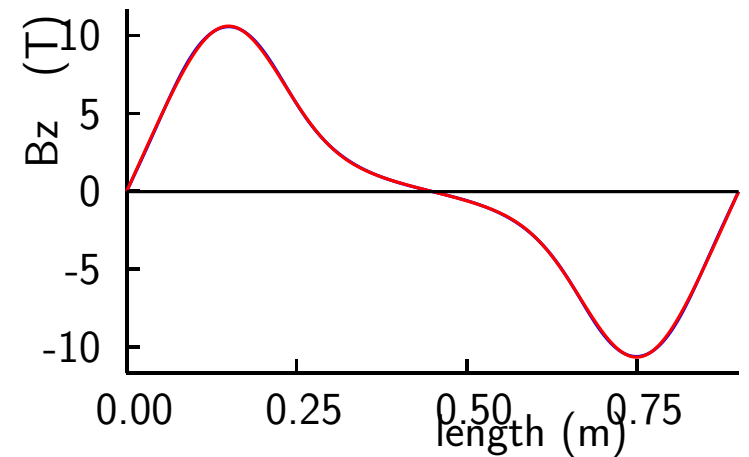
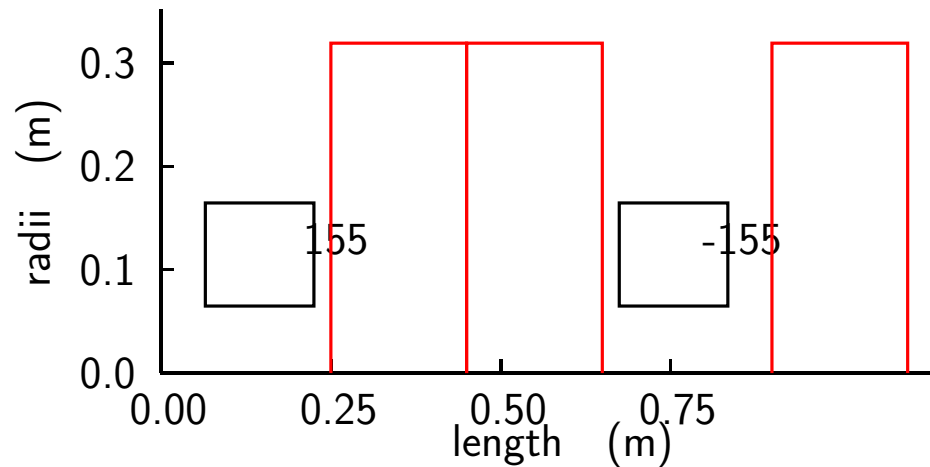
# Mag Insulation of Guggenheim



- Surface fields now  $\approx 2$  times acceleration
- Shunt impedance worse
- Higher content of Fourier content in B vs z
- Because used for so much cooling losses are unacceptable (3% vs 7% transmission)

# 805 MHz Guggenheim has to be different

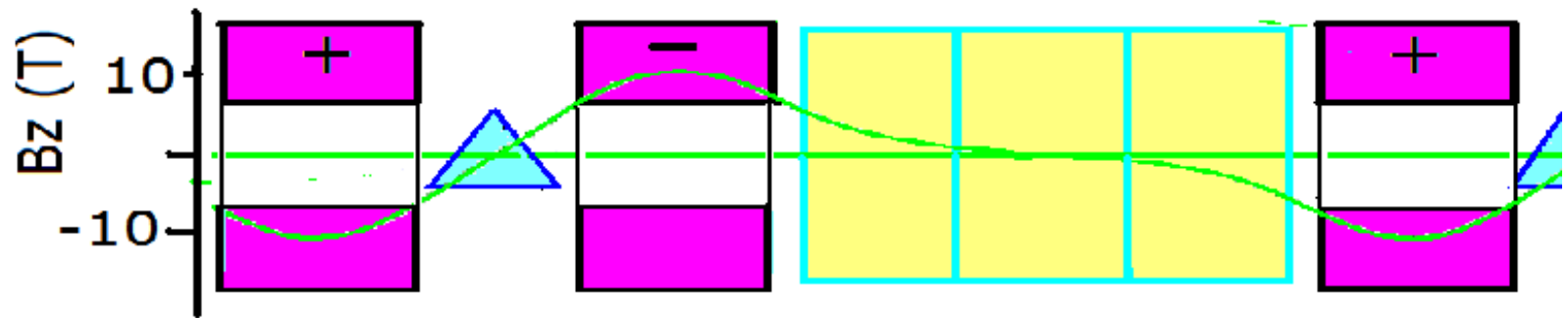
Not practical to put 10-12 T solenoids outside rf



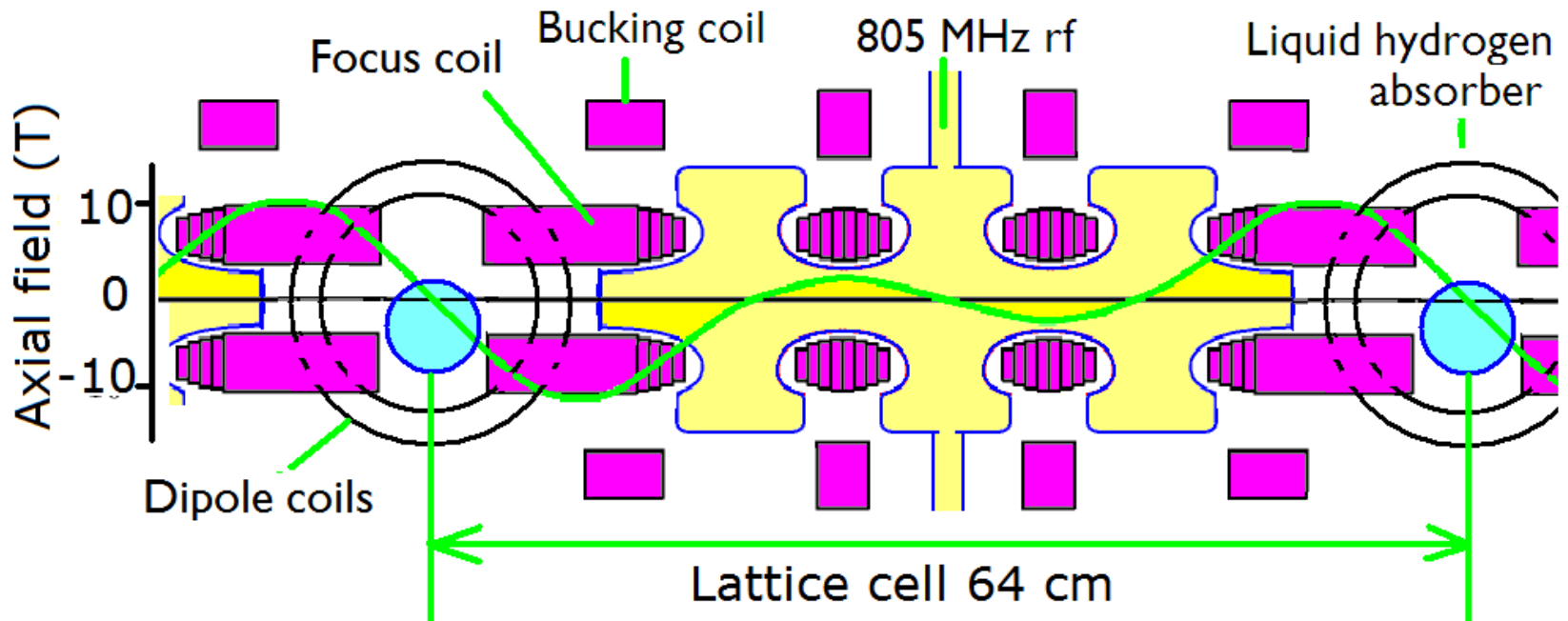
- Less efficient ( $Q \approx 8$ ) but only needed for limited cooling so ok

# Mag-Insulated version of 805 MHz lattice

Old  
simulated  
lattice



Mag Ins  
version  
Not yet  
simulated



Magnetically insulated version has similar fields to standard version and will probably show similar performance

## Summary

Stage	rf freq MHz	emit(equ) $\pi$ mm	B(solenoid) T	B(lattice) T	ratio
1	201	2	3.75	2.6	0.7
2	401	1	7.5	5.2	0.7
3	805	0.32*	23	12*	0.52

\* Scaled from lattice shown

## Conclusions

- Periodic lattices allow lower  $\beta$ s for same magnetic fields
- Double periodicity lattices give greater momentum acceptance
- Simulations of lattices with coils outside give good efficiency
- Magnetically insulated lattices have worse performance
- One hopes that Be Cavities will solve the problem  
at least for higher frequencies
- Alternatively: HCC or FOFO gas filled lattices ok for 201 and 402 MHz stages,  
but these will not have factor 2 gain from focusing
- Magnetically insulated 805 MHz probably acceptable for cooling to lowest emittances